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(54) Title: METHOD AND APPARATUS FOR CONTROLLING ENCODING RATE IN A COMMUNICATION SYSTEM

(57) Abstract

A code division multiple access (CDMA) communicating system reduces interference by reducing the encoding rate for selected mobiles. The system (400) primarily uses link related characteristics such as, inter alia, distance measurements, physical resource power, and mobile determined noise, to determine which mobiles require an encoding rate reduction. Once determined, the encoding rate of the determined mobiles is reduced, which in turn reduces self-interference and enhances system capacity.

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METHOD AND APPARATUS FOR CONTROLLING ENCODING RATE IN A COMMUNICATION SYSTEM

5   Field of the Invention

The present invention relates to communication systems and more specifically to controlling encoding rates in such communication systems.

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Background of the Invention

In recent years a variety of techniques have been used to
15   provide multi-user mobile communications within a limited
available radio-frequency spectrum. These methods have
included frequency division multiple access (FDMA), time
division multiple access (TDMA), and code division multiple
access (CDMA) or, more usually, hybrids of these methods. All of
20   these methods have been employed within the past decade in the
design of commercial cellular telecommunications systems:
witness the use of FDMA in the North American AMPS system,
FD/TDMA in the European Groupe Speciale Mobile (GSM)
standard, and – more recently – the adoption of a direct sequence
25   FD/CDMA approach by the United States Telecommunications
Industry Association as embodied in its IS-95 standard. In the IS-
95 standard, subscribers share one of several wideband radio
channels in the cellular band. Several proposals for so-called
personal communications systems (PCS) are also being designed
30   on similar FD/CDMA principles.

Almost all recent cellular and PCS systems have used
digital speech encoding and forward channel error correction as
the physical layer for voice communication. More interesting, in
this context, is the use of voice activity detection (VAD) to

recognize the presence or absence of speech on the part of the either calling party. In the absence of speech, the speech encoder may instruct the modulator or transmitter to which it is linked to reduce its output power to zero, or transmit occasional packets of information describing only the background noise at the either user's location. Reducing the radio transmitter's duty cycle in this fashion provides the twin benefits of a reduction in power consumption (which increases battery life in the case of the mobile unit) and a reduction in interference between users sharing the same RF spectrum. Depending on the circumstances of the conversation, a reduction in transmitted power of between 40% and 65% can be achieved. The amount of power reduction is ultimately limited by the extent to which the degraded voice quality which accompanies significant VAD techniques is considered acceptable.

The possibility of power reduction is particularly important for CDMA systems. In such systems, user capacity is inversely proportional to the amount of system self-interference. In the TIA IS-95 FD/CDMA standard, a variable rate speech encoder is used in place of simple on-off or discontinuous transmission methods. The TIA IS-96 standard — which describes the speech encoder and decoder which accompanies the IS-95 system — divides the source 64 kbps PCM speech samples into 20 ms intervals or frames. The speech encoder then elects to encode each frame at a effective bit rate of 8000 bps, 4000 bps, 2000 bps, or 800 bps. Both the base-station to mobile station (forward) and mobile station to base-station (reverse) IS-95 links exploit this variable rate encoding method. In the case of the forward link, mean transmit power is reduced by scaling down the output power as the encoded rate decreases. Channel symbol repetition allows symbol combining at the mobile receiver and hence maintenance of the energy per symbol to noise power spectral density ratio which determines link performance. While variable rate transmission has little

3

benefit in terms of power consumption at the base station, it should be noted that mean transmit power – and hence system self-interference – is reduced by a factor of four during 800 bps transmission. By averaging over the aggregate voice activity for typical two-way conversations, it has been estimated that when using the standard speech encoding and voice activity detection algorithm defined in TIA standard IS-96 the mean transmit power will drop to around 41% of its nominal value. This has a significant effect on both system forward and reverse link capacity.

As a cellular mobile communications system designed on CDMA principles (such as TIA standard IS-95) approaches periods of peak tele-traffic demand, it is possible to temporarily increase overall system capacity at the expense of reduced voice quality. One way of achieving this is to force the mean transmitted bit rate on both the forward and reverse directions of a link to lower levels than would normally be selected by the TIA IS-96 rate determination algorithm. This can be done by simply placing an upper bound on the rate that may be selected by the rate determination algorithm at either end of a link. A slightly more sophisticated approach is to vary this upper bound on a duty-cycle basis. For example, a user might be allowed to transmit two frames using full-rate as the maximum allowable rate, then a single frame at a maximum allowable rate of half-rate, with the cycle then repeating. The duty-cycle ratio and allowable rates determine the mean reduction in transmitted power over that delivered by a constraint-free speech encoder. Clearly this technique includes less sophisticated VAD schemes where, for example, only a full-rate and a background noise description rate exist. It may be even be extended to systems in which only a single rate exists. In that case encoded speech frames are simply blanked (that is, not transmitted) with the receiving speech decoder performing interpolation or frame substitution to reconstruct the missing speech waveform segments.

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Thus a need exists for a system and technique which may increase system capacity without sacrificing voice quality in the above-mentioned environment.

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Brief Description of the Drawings

FIG. 1 generally depicts, in block diagram form, a prior art CDMA base-station transmitter.

10   . FIG. 2 generally depicts, in block diagram form, the receive side of a CDMA base-station.

FIG. 3 generally depicts, in block diagram form, a combination of demodulated reverse link signals simultaneously received by a plurality of base-stations from a single mobile station

15   in accordance with the invention.

FIG. 4 generally depicts, in block diagram form, a transmitter which may implement speech rate control in accordance with the invention.

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Detailed Description of a Preferred Embodiment

A code division multiple access (CDMA) communication system reduces interference by reducing the encoding rate for

25   selected mobiles.   The system primarily uses link related characteristics such as, inter alia, distance measurements, physical resource power, mobile determined noise, to determine which mobiles require a encoding rate reduction. Once determined, the encoding rate of the determined mobiles is reduced, which in turn

30   reduces self-interference and enhances system capacity.

The technique of enforced speech encoder rate reduction to achieve increased system capacity can be significantly improved by realizing that the propagation loss between the mobile station and

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base-station is generally a geometric function of the distance which separates them. Accordingly, mobile stations which are operating in a cell at some distance from their serving base-station make a disproportionate contribution to the interference experienced at base-stations serving adjacent cells. This is a direct consequence of the need for distant mobile stations within a cell to transmit more power in order to sustain the necessary signal to noise (S/N) ratio at the receiving base-station to ensure reliable demodulation. The effect is compounded by the fact that such mobile stations are generally positioned closer to the adjacent base-stations with which they are interfering than with the serving base-station. This results in a corresponding reduction in path loss, and consequent increase in interference. Such mobile stations are also the primary source of interference on the forward link, since they make most demands on the transmitted power of a serving base station, with attendant increase in the system self-interference experienced both by mobile stations in adjacent cells and (depending on the spreading codes used and the amount of channel time dispersion) those in the same cell. This observation is already exploited in so-called "soft handoff" methods, in which a mobile station establishes simultaneous links with one or more base-stations in order to reduce the overall system self-interference.

If mobile stations which are distant from their serving base station, or base stations, could be identified and selected for rate reduction, system capacity is increased by almost as much as if rate reduction had been applied to all mobile stations regardless of their position within the cell. This in turn restricts the loss of voice quality which accompanies rate reduction to only the selected subset of mobile stations rather than the entire population with a resultant improvement in overall system voice quality.

6

The communication system controls encoding rate by
determining link related characteristics from a plurality of mobiles
and controlling the encoding rate of certain mobiles based on the
determined link related characteristics. Link related characteristics
5   include, but are not limited to, the handoff state of a mobile (soft
or hard handoff state), the location of a mobile (with respect to
serving base-station or adjacent base-stations), transmission
characteristics of the mobile (for example, the current transmission
level of the mobile), transmission characteristics of a serving base-
1 0   station (for example, the current transmission level of the serving
base-station) and the amount of acoustic background noise
experienced by the mobile (for example, the amount of acoustic
background noise experienced by the mobile during
communication with a serving base-station).
1 5   The preferred embodiment of the invention is described as
it relates to a CDMA digital cellular telecommunications system
based on the Telecommunications Industry Association standards
IS-95 and IS-96. It will be appreciated by one skilled in the art that
the invention may be applied to any CDMA communications
2 0   system to which self-interference reduction by variable rate speech
encoding is to be applied.   The technique may likewise be
beneficially utilized in any TDMA communications system, such
as the GSM TDMA communication system, as well.
FIG. 1 shows the high-level architecture of the forward link
2 5   of a CDMA base-station (102) designed for the preferred
embodiment of the TIA IS-95 digital cellular radio standard. The
base-station (102) of FIG. 1 performs, inter alia, variable rate speech
encoding, forward error correction, forward link power control,
multiple access spreading, and modulation and transmission. In
3 0   FIG. 1, several standard μ-law encoded, multiplexed, 64 kbps pulse
code modulated (PCM) T1 links (101) from the public switched
telephone network (PSTN) (100) are brought to a demultiplexer
(103). Each 64 kbps voice link (104) is then passed through a digital

speech encoder (105). In a conventional implementation, the speech encoding function is performed by a number of general purpose digital signal processors (DSP's) such as the Motorola DSP56156 processor, ROM coded DSP's, or application specific

5   integrated circuits (ASICs). Several such processors are generally grouped onto a single printed circuit board (although this is not necessary for the invention) which is then capable of processing a full T1 trunk of multiplexed voice channels. After speech encoding, error correction (106) is applied in the form of

10   convolutional and cyclic codes, followed by BPSK baseband modulation (107), Walsh cover and short pseudo-noise (PN) sequence spreading (108), low-pass filtering (109), transmit power level adjustment (110) and power amplification (111), and finally transmission to the mobile station (113) (for simplicity, frequency

15   shifting to RF is not shown).

FIG. 2 depicts the high-level architecture of the receive side of CDMA base-station. In general, FIG. 2 shows one of many individual receivers which comprise the base-station and which perform multiple access signal despreading, antenna combining,

20   demodulation, forward error correction decoding, and speech decoding. Specifically, it shows one of several receivers (200) which exist within a base station, and which support multiple reverse connections into the PSTN (100). The RF circuitry of each receiver consists of a spatially diverse antenna system (209), and

25   preamplification circuitry (208) (for simplicity AGC and filtering functions are not shown). Despreading of the user-specific pseudo-noise (PN) spreading sequence used to provide multiple-access takes place in the PN despreader (207) which consists, in the preferred embodiment, of a complex multiplier and an integrator.

30   Note that in order to achieve PN sequence synchronization with the mobile station's transmitted signal, it is necessary in the preferred embodiment for each receiver to retard (relative to a global system time reference) its internally generated PN sequence

by approximately twice the one-way RF propagation delay between the base-station and mobile station. This parameter appears in FIG. 2 as the required PN phase (206). Methods for initially estimating (by sequential search, for example) and then tracking

5   (by delay lock loop, for example) this phase offset are well known and will not be described here. For completeness, FIG. 2 shows two despreader units. Each is attached to a single antenna of a second-order spatial antenna diversity system. Where time dispersion exists on the channel, more despreader units may be used. In the

10   context of this invention, the time delay (or equivalently, PN phase (206)) of the first arriving component of a dispersive channel is that used in accordance with the invention in the manner described below. Completing the description of FIG. 2, following non-coherent demodulation (205) of the underlying 64-

15   ary orthogonal signaling, and symbol combining (204), forward error correction decoding (203) is performed before speech frame rate determination (202) and finally speech frame decoding to 64 kbps μ-law PCM format (104). Multiplexing to T1 format (101) and injection into the PSTN follows.

20   FIG. 3 shows an elaboration of the FIG. 2 in which a single speech decoder (201) is no longer associated with a single reverse link receiver, but rather may accept demodulated encoded speech frames from any one of several receivers each of which may be housed in a different base-station (301). The speech decoder

25   operates on frames chosen by the selector function which, operating under the control of the mobile telephone switching office (MTSO), accepts for decoding a single 20 ms encoded speech frame from the three frames offered by the base stations. Such a configuration is sometimes referred to as "soft-handoff" or

30   "macro-diversity". Each receiver demodulates the same reverse link signal from the mobile station. In FIG. 3, three base-stations (301) are shown, although there is no limit to the number of base-stations which may be combined in this manner. Note that a

selector function (300) has been introduced to identify, on the basis of a cyclic code parity check or some other demodulation quality metric, which of the three encoded speech frames should be accepted for decoding by speech decoder (201). Overall control is provided by MTSO (304) which has identified, by instructing RF signal strength measurements to be made at the base-stations or by receiving signal strength measurements of each base-station signal strength made by the mobile station, that the mobile station is in a location in which roughly comparable path loss exists between each of the base-stations and the mobile unit.

With this background, speech rate control for CDMA forward link in accordance with the invention may now be described. FIG. 4 shows a rate controller (400) controlling the rate selected by the speech encoders (105) operating on the forward link. The rate controller (400) accepts a number of different parameters as input; these include inputs from a) the MTSO (304) regarding the soft decision handoff state of the mobile to which the speech encoder is assigned, b) the transmit power control RF circuitry (110) regarding the transmit power level at which the forward link assigned to the mobile station is operating, and c) the PN phase of one or all of the receivers which are currently demodulating the reverse link of the mobile station, and for which the estimated mean energy per bit to noise power spectral density ratio is sufficiently high to provide an accurate PN phase estimate (that is, for which the estimated mean energy per bit to noise power spectral density ratio is above a predetermined threshold which indicates that the receiver is in a locked state – again, methods for establishing this condition are well known and will not be described here). The rate controller (400) then identifies those mobile units which are at greater distance from the serving base station(s) as a precursor to preferentially performing rate reduction on those mobiles. Rate controller (400) makes rate selection decisions for a variable rate speech encoder or places bounds on

the rates which may be independently selected by that the rate determination procedure associated with that encoder.

It will be clear that given the information provided to the rate controller (400), rate control can be done in a variety of ways.

5 The distance for each base-station can be estimated by using the transmit power level required to close the forward link. Obtaining the forward link path loss allows the base-station to mobile station separation to be calculated by using one of several available mathematical models relating path loss to distance, or by using

10 measured propagation measurements from the cell in question. An alternative method would establish the base-station to mobile station separation from the measured PN phase (206) by simply calculating the one-way propagation delay from the chip rate (1.2288 Mchips/s in the preferred embodiment), and then

15 multiplying by the velocity of light. A more accurate method would use the distance estimate provided by the PN phase of all the base-stations (301) demodulating a mobile, possibly in concert with knowledge of the geographical location of the base stations, to establish the position of the mobile station by triangulation.

20 Alternatively, since the MTSO has already implicitly established that the mobile station is roughly equi-distant from two or more cells by placing the mobile station in soft handoff status, this condition alone would be sufficient to identify the mobile station as a primary candidate for rate reduction. Finally, some

25 combination of these parameters may be used.

Speech traffic channels or systems are not the only ones which could benefit from the invention. In a data application, the invention could be utilized to adjust the permitted rate of transmitted data to and from a mobile station. It would also be

30 possible to prioritize data transmissions to be reduced or suspended before speech, so to minimize user perceived speech degradation.

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          Applications may permit this invention to be autonomously employed by the base or the subscriber unit. For example, a subscriber unit might sense that capacity limits are being reached. If in the soft handoff condition or needing a high

5   transmitter power, the subscriber unit might preferentially try to encode its speech using a lower effective average bit rate or reduce the transfer rate if transmitting data. Of course, the base could do similarly.

          It is clear that the proposed technique can be extended for

10   use in any digital cellular system which can control the transmission of information to and from a subscriber in a manner that affects generated interference. For example, one other application besides DS-CDMA includes frequency hopping where voice activity or variable rate can be controlled.

15   While the invention has been particularly shown and described with reference to a particular embodiment, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

20   What I claim is:

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Claims

5   1.   A method of controlling encoding rate in a communication
system, the method comprising the steps of:

      determining link related characteristics from a plurality of
mobiles; and

10   controlling the encoding rate of certain mobiles based on the
determined link related characteristics.

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2.   The method of claim 1 wherein link related characteristics further comprise either the handoff state of a mobile, the location of a mobile, transmission characteristics of the mobile, transmission characteristics of a serving base-station and the amount of acoustic background noise experienced by the mobile.

3.   The method of claim 2 wherein the location of a mobile further comprises the location of the mobile with respect to either the serving base-station or adjacent base-stations.

4.   The method of claim 2 wherein the transmission characteristics of the mobile further comprise the current transmission level of the mobile.

5.   The method of claim 2 wherein the transmission characteristics of the serving base-station further comprise the current transmission level of the serving base-station.

6.   An apparatus for controlling encoding rate in a communication system, the apparatus comprising:

    means for determining link related characteristics from a
5 plurality of mobiles; and
    means, coupled to the means for determining, for controlling the encoding rate of certain mobiles based on the determined link related characteristics.

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7.   The apparatus of claim 6 wherein link related characteristics further comprise either the handoff state of a mobile, the location of a mobile, transmission characteristics of the mobile, transmission characteristics of a serving base-station and the

5   amount of acoustic background noise experienced by the mobile.

8.   The apparatus of claim 6 wherein the handoff state of a mobile further comprises either a soft handoff or a hard handoff state.

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9.   The apparatus of claim 6 wherein the transmission characteristics of the mobile further comprise the current transmission level of the mobile.

15   10.   The apparatus of claim 6 wherein the amount of acoustic background noise experienced by the mobile further comprises the amount of acoustic background noise experienced by the mobile during communication with a serving base-station.
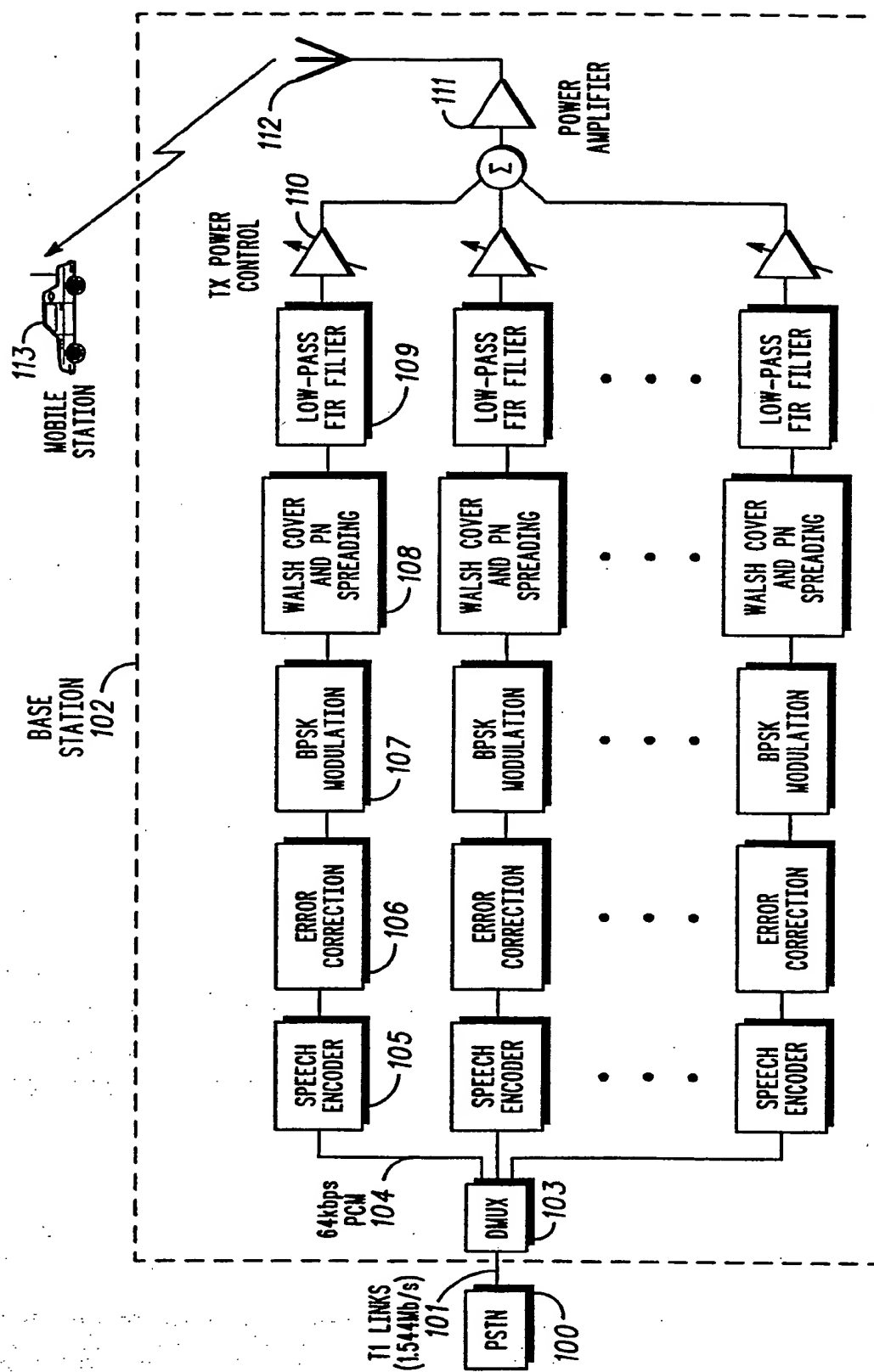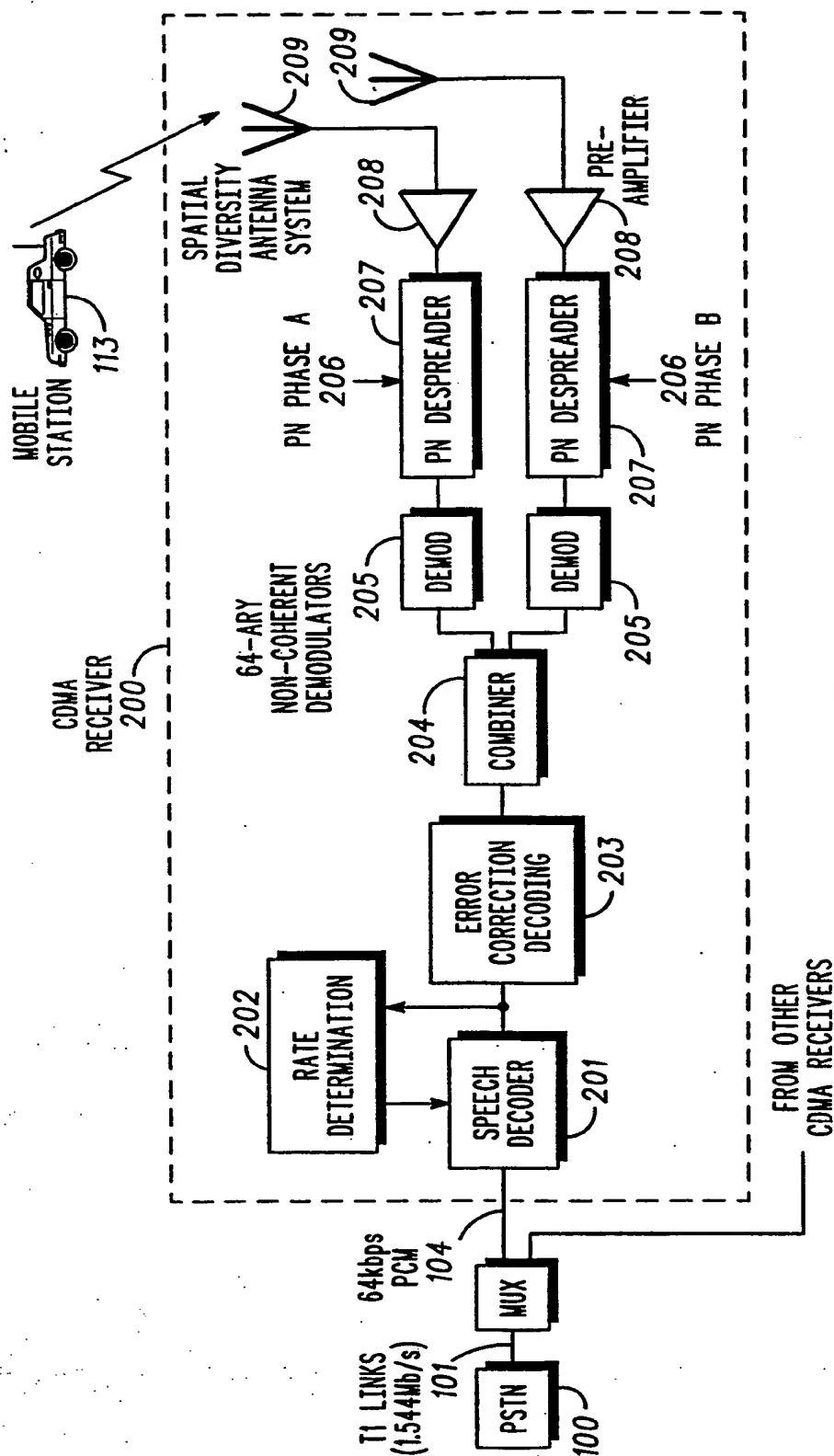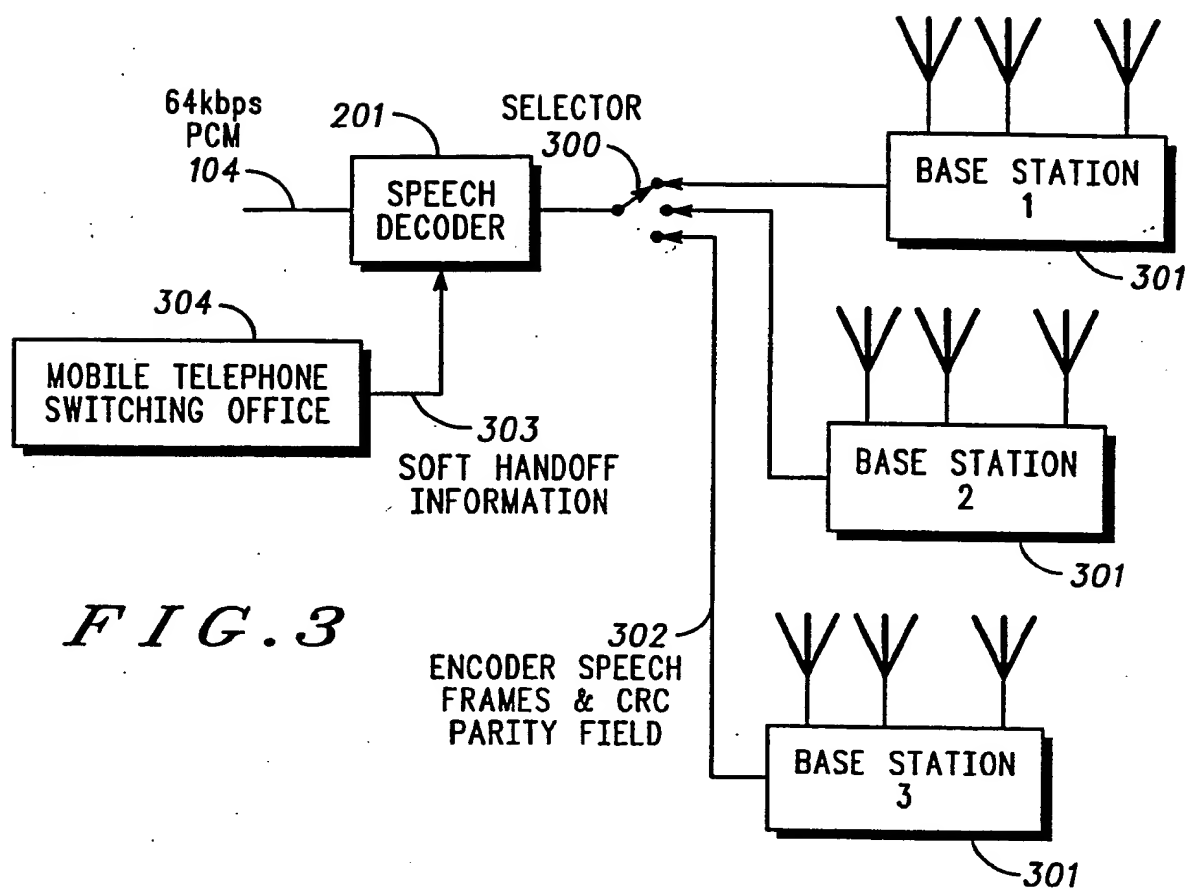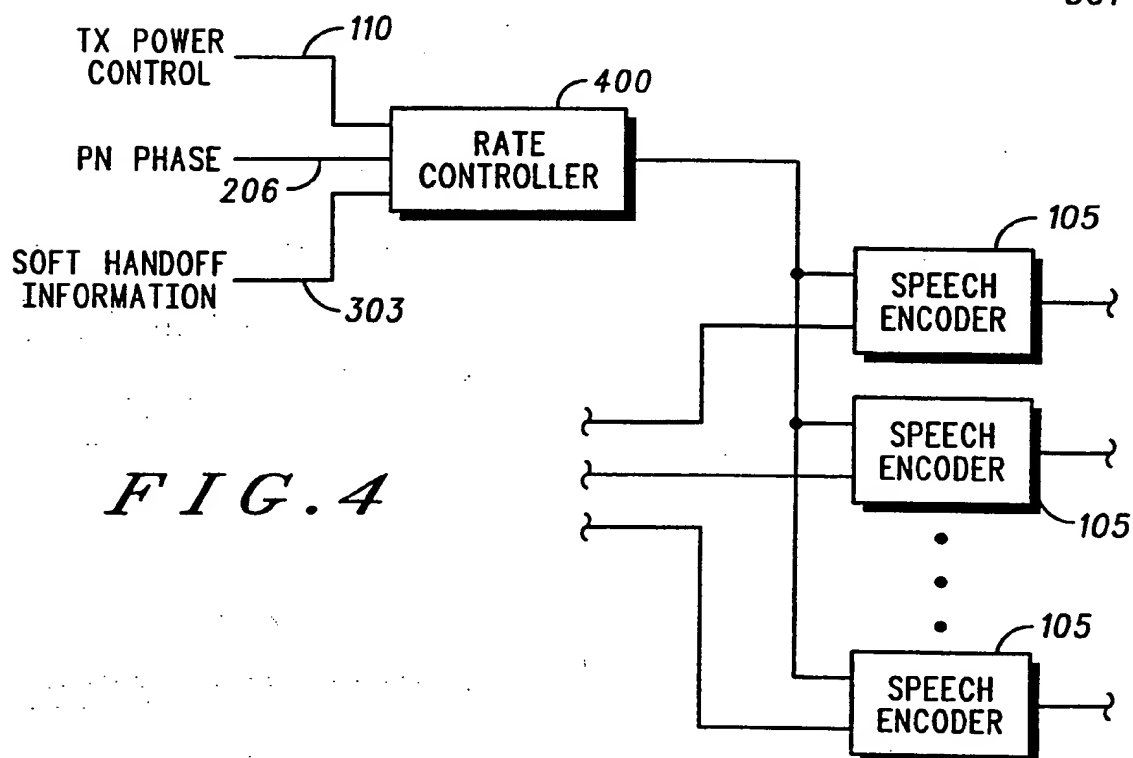
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FIG.1

2/3

FIG.2

FIG.3

FIG.4

INTERNATIONAL SEARCH REPORT

A.	CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04B1/10: H04Q 17/00, 7/38
US CL : 455/63, 33.2, 54.1, 56.1, 67.1 379/60

According to International Patent Classification (IPC) or to both national classification and IPC

B.	FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 455/33.1-33.3, 33.4, 54.1, 56.1, 63, 67.1, 67.4, 68-70: 379/59, 60: 395/2.23,2.35, 2.38

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C.	DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, P	US, A, 5,341,456, (DEJACO) 23 August 1994, col. 4, lines 23-39 and col. 5, lines 22-35.	1-10
Y	US, A, 5,070,536 (MAHANY ET AL.) 03 December 1991, col. 2, line 29 - col. 3, line 36, col. 7, lines 9-52, col. 2, lines 32-35.	1-10
Y, P	US, A, 5,309,474, (GILHOUSEN ET AL.) 03 May 1994, col. 31, lines 8-27, col. 24, lines 7-25.	2-10

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 MARCH 1995	10 APR 1995

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